SCHEDULE: STILL ON TIME?

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Abstract

The status of installation across the LHC will be given with particular attention to Sector 78 and 81. This will illustrate some of the difficulties encountered during the past year and limitations related to co-activities in narrow underground areas. The talk will then describe how to profit from the experience gathered on the two first LHC sectors with a view to limit the impact of the delays accumulated so far.

INTRODUCTION

We will first review the present status of the LHC hardware installation and then give an estimate of the evolution of the delays of the main components versus the present master planning.

The situation a year ago, in January 2005, can be summarized as follows:

- Civil engineering just finished a couple of months earlier, last underground area to be delivered was RB/UJ56 at Point 5 by mid-November 2004;
- The general service phase was almost completed all around the ring, but the collimation region at Point 7 was just re-designed and all services in LSS7L/R had to be re-installed;
- The QRL in Sector 7-8 had to be repaired and re-installed, there were only 2 validation cells ready in Sector 8-1;
- The production of the cryo-dipoles was running full swing, and we had to struggle to store at the surface some 480 magnets that we could not transport in the tunnel since the situation of the QRL did not allow to free any underground slot.

This situation led us to revisit the planning, with a view to maintain the objective to circulate the first LHC beams by summer 2007. This compressed installation planning assumed several shortcuts, as skipping the QRL cold tests after the first 2 sectors (7-8 & 8-1). It also introduced parallelism between major activities, such as cryo-magnet installation and interconnection while QRL installation and testing is still on-going in that sector. The delays discussed in this paper all refer to this compressed installation planning that was issued April 1st , 2005 [1].

STATUS OF LHC INSTALLATION

QRL Installation

The completion of the QRL installation triggers a variety of new activities since it frees slots where we can install cryo-magnets. CERN took over the repair and the re-installation of Sector 7-8, which allowed giving first priority to the completion and tests of the two sub-sectors close to Point 8 (sub-sectors A & B). The master schedule assumed that these first cold tests of the QRL in the tunnel would be carried in July 2005, they finally started by mid-September. Moreover, the completion of the full cryo-line of Sector 7-8 was expected for September, it was achieved by the end of the year. The situation in Sector 8-1, where the QRL is installed by Air Liquide, shows a similar pattern: cold tests were expected for September, they were carried in December. This altogether leads to attribute a 3 months delay to the QRL activity.

Power tests in LSS8L and availability of DFB's

Once the first 600m of QRL were installed and tested, we could foresee the installation and power tests of the cryo-magnets in the long straight section left of Point 8. This early rehearsal of the hardware commissioning was scheduled for the end of 2005, but it had to be postponed since the cryogenics current feed boxes (DFB's) to power D2-Q5 and Q6 were not available. The DFBMA/C were expected for September 2005, but their availability is now estimated for February 2006, 5 months behind our schedule. However, the power converters were installed and tested at Point 8, in UA83, according to the planning.

Cryo-magnet transport

As already mentioned, the compressed installation planning assumed that cryo-magnets would be transported underground as soon as a sub-sector of the QRL would be installed and leak tested. According to the installation schedule of Sector 7-8, all arc and dispersion-suppressor (DS) magnets would have been in place by September, and those in LSS8L by October 2005: we in fact had, by the end of the year, 40 dipoles and 17 short straight sections (SSS) in the arc and, in LSS8L, only the Low-β quadrupoles and D1/D2/Q4 were in place, Q5 being non available yet. Concerning Sector 8-1, the arc and DS magnets were expected in place by September: we had 111 dipoles and 18 SSS's transported by the end of the year (note that the installation had to stop in 8-1 for 6 weeks due to the cold tests of the QRL). Finally, all magnet in the arc and DS of Sector 4-5 should have been in place by the end of 2005, there were only 48 dipoles and 9 SSS's transported by that time. As a summary, instead of about 600 cryo-magnets transported in 2005, we had a score of 248, representing a delay of 4 months when considering the nominal rate of 20 magnets per week, a rate that was indeed achieved during the 2 weeks of January 2006 preceding the Workshop.

It is worth mentioning that under the header "cryo-magnet transport problems" there is a mix of unavailability of slots liberated by the QRL, of magnets that are not available on time and, last but not least, pure transport vehicle issue:

- On many occasions, leak testing and repairs took much longer than anticipated and the corresponding QRL sub-sector was not ready on time for magnet

installation. Moreover, about 15 service modules in Sector 8-1 need to be repaired, and some leaks appeared in Sector 4-5 after the pressure tests in December, and this precludes cutting the jumpers in those sectors, which in turn does not free the corresponding SSS slots.

- We had to face many non-conformity problems with the dipoles in summer 2005, due to the so-called "collarette" welds, but the situation has been cleared since and all required dipoles are now available on time. The situation is however more tight with the SSS with plugs (required to sectorise the magnet string) and with special SSS's, in the straight sections and in the DS, that are still late.
- Among the most disturbing problems we experienced with the transport vehicles, one should quote the need to replace all breakers on the powering line, the replacement of the safety valves on the unloading equipment and the oil overheat when driving on long distances. We also had difficulties maintaining a clean guiding line and insuring a good lubrication of the wheel axles that lead to some un-reliability of the transport system.

Cryo-magnet interconnect

The connection of the cryo-magnets in LSS8L was expected for November 2005 but it has not started yet, and only 29 interconnects are in progress in Sector 7-8 when we expected 50% of the arc done by the end of the year. Concerning Sector 8-1, the schedule indicates that 70% of the arc should be done by the end of the year when only 52 interconnect are in progress. This is a new activity where some ramping up is expected, one can evaluate the delay to 3 months on the basis that it takes 6 months to interconnect a Sector.

To summarise this first part on the status of the LHC installation, we presently have a minimal delay of 3 months with up to 5 months on the procurement of certain elements. We however got experience with many new installation activities that started during year 2005 such as QRL pressure and cold tests, magnet transport and interconnection, installation and tests of power converters. We also learned that leak tests and leak finding are very delicate and require more time than anticipated. It is also clear that piling up co-activities in a narrow tunnel lead to a situation where small incidents have large impacts on the overall installation efficiency.

EVOLUTION OF THE INSTALLATION DELAYS

The question now is how to limit the increase of the delays accumulated on the installation of the LHC? The answer has to take account of hard constraints on the rate of installation of the QRL, on the magnet transport capacity, on the procurement of special SSS and of the DFBs. The rate and test procedure of the cryo-magnet interconnects allow to foresee the dates when each sectors would be available for hardware commissioning.

QRL Plans

A revisited schedule of the QRL installation was issued late November 2005, taking account of the actual situation in the tunnel and of the achieved rate of production of the QRL elements. This schedule also assumes that the installation teams would install on 2 sectors in parallel, and would not end working in 3 sectors at the same time, as it was anticipated with the previous scenario from Air Liquide. This new schedule expects that the QRL installation would be achieved by November 2006, and this is about 3 months behind our planning: we can thus expect to maintain the present delay on the QRL installation.

Cryo-magnet transport rates

The transport of the cryo-magnets is achieved by mean of 6 vehicles with specific characteristics:

- 2 "CTV" type convoys can handle the long arc and DS dipoles;
- 2 "MCTV" type convoys can handle all cryo-dipoles and the long special SSS (>8m);
- 2 "STV" type convoys can handle the arc and the short special SSS.

There are 1296 elements in total to transport with CTV and MCTV vehicles: 1232 main bending dipoles, 24 long special SSS and 16 insertion cryo-dipoles. At the time when writing this paper, there was 240 of them in place, thus 1056 still to transport. Counting on 3 CTV and MCTV convoys available at any time while one vehicle is on maintenance, we can actually transport 15 such cryo-magnet per week, and expect to raise this rate to 18 per weeks after mid-April when an extra team would allow working on Saturdays. This would then allow transporting all dipoles by March 2007, which is 3 months behind our planning. We also plan to transport the SSS through Point 6 when installing Sectors 5-6 and 6-7, and this should catch back the delays accumulated with the SSS transport.

Provision of special elements

There has been a recent review of the production of the SSSs with an overview of the different steps from cold mass production to final preparation for installation in the tunnel. A reallocation of resources, such as the number of benches allocated to SSSs cold tests in SM18, allows scheduling the procurement of all cryo-magnets, ready for installation in the LHC tunnel, by March 2007.

The fabrication of the power feed boxes, the DFBs, is less advance and, as already mentioned, the DFBM for le long straight sections left of Point 8 are lagging 5 months behind our installation planning. The present production schedule of the DFBs is summarised in Table 1: the date for sector 8-1 is obviously very late when compared to the installation of the cryo-magnets that should end during the first quarter of 2006. Moreover, the production of the DFBs does not follow the natural installation of the LHC

sectors: the DFBs for sectors 3-4 and 5-6 would be available before those of sector 4-5.

Sector	Latest DFB in sector
7-8	15-Apr-06
8-1	15-Jul-06
4-5	15-Sep-06
3-4	11-Aug-06
5-6	07-Sep-06
6-7	23-Oct-06
1-2	02-Dec-06
2-3	04-Feb-07

Table 1: DFB production schedule

Interconnection activity and availability of sectors for hardware commissioning

The interconnection of the cryo-magnets, first phase, contains many different steps:

- Welding of lines V1, V2, E, X, C', K2, brazing of BP, spool pieces circuits, Y: this is done interconnect by interconnect and take about 8 days.
- Partial assembly qualification (PAQ) [2], which requires a full ½ cell installed and takes about one day.
- Welding of lines M1, M2, M3, K1 done over ½ cell and takes another day.
- Insertion of line N over ½ cell plus the adjacent SSS, takes 3 days, followed by line N cabling that last another day.
- Assembly interconnect verification (AIV) [2], test of a full ½ cell together with its two neighbouring ½ cells on both sides, last 3 days.
- Provisional closure of the external bellows, interconnect by interconnect, takes about 4 days.
- Vacuum tests over a vacuum segment between 2 SSSs with plugs (usually 2 full cells), that last about 2 weeks.

We assume that the initial welding activity progress on a front at the rate of one interconnect per day. Putting all the activity in sequence, taking account of the ensemble needed to perform the different tests, one can evaluate that 9 weeks are required between the end of the cryo-magnet transport and the end of the first phase of the interconnect within a sector. However, if a single element comes late, as a DFB, many welds and tests could already take place before the installation of this element: in such a case, about 6 weeks are required between the installation of this single element and the end of the first phase of the interconnect.

A global pressure test of the entire sector is performed after the first phase of the interconnect activity, and it is assumed to last 2 weeks. It is followed by the re-opening of the external bellows to install thermal shield and the multi-layer insulation, and the final closure of the cryostat: this second phase of the interconnect activity, often referred as interconnect closure, also contains the consolidation of the leak tests: a total of 8 weeks are allocated to this second and final phase of the interconnection of the elements within a sector.

The time required to perform all the steps of the interconnect activity takes 95 days after the transport of all cryo-magnets or 80 days after the installation of the DFB boxes. The dates when each sector would be available for hardware commissioning can be read on Figure 1.

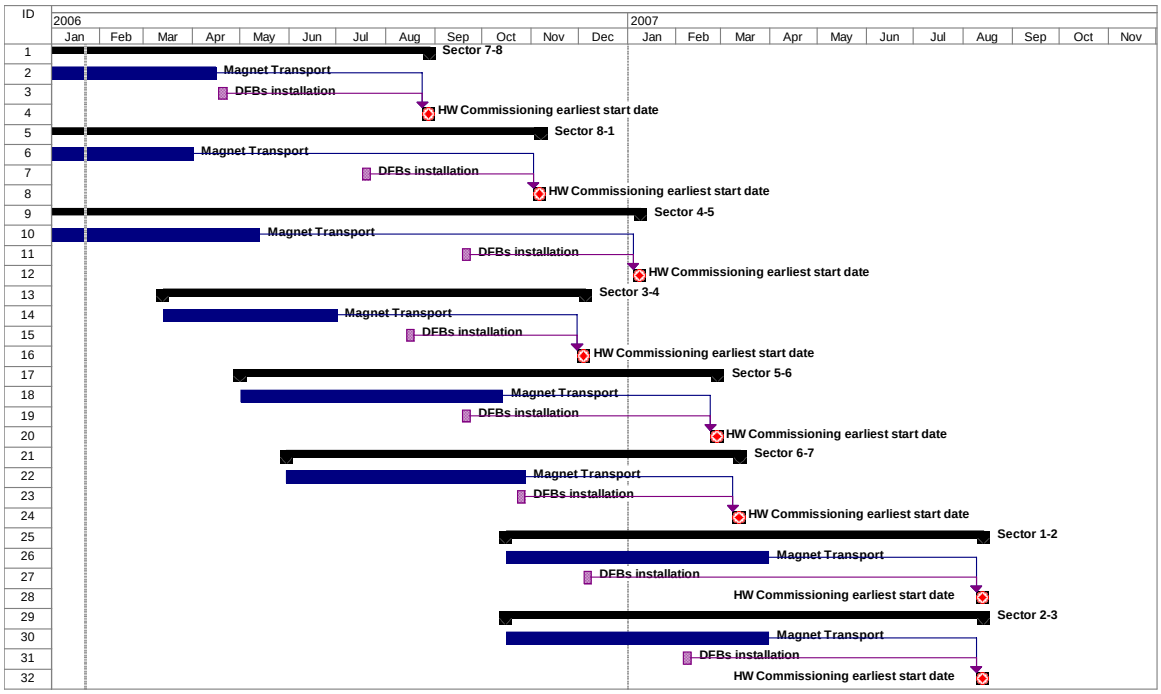

Figure 1: Earliest start dates of hardware commissioning of the LHC sectors

CONCLUSIONS

Many new installation activities started in 2005 and a lot of them are now in a ramping-up phase: installation and tests of the QRL, preparation and underground transports of cryo-magnets, alignment and interconnect of magnets in a difficult environment. The situation is totally different from what it was a year ago and we now have gained experience in the field, dealing with intricate logistics and organization of co-activities in a narrow tunnel with a limited number of access shafts. We also learned to organize the work with enough flexibility to cope with unexpected incidents, such as late leak detection and repair that consumes much more time than initially anticipated.

The delays accumulated are of the order of 3 months when comparing the status of the installation with the schedule issued beginning of 2005. The QRL installation, which is on the critical path since it frees the slots required for the installation of the cryo-magnets, was the main contributor: it is now well under control and we can be confident that it will not contribute to new additional delays. Moreover, the teething problems encountered with the logistics of the cryo-magnets and their underground transport are now solved, and we can plan for an increase of the installation rate above the nominal 20 cryo-magnets per week.

The procurement of some special components is however still worrying. The preparation of the cryo-feed boxes (DFBs) that insure the warm-cold transition of the current leads, is on the critical path and will impact on the starting dates of the hardware commissioning phase of many sectors: it is in particular the case for Sector 8-1 which is required for the test with beam scheduled for the end of 2006 [3]. The present schedule of the DFBs also imposes drastic time and geographical constraints for the hardware commissioning, and needs to be revisited.

REFERENCES

[1] LHC Construction and Installation, General Co-ordination Schedule, EDMS Document N° 102509.
[2] Polarity and electrical quality assurance – S. Russenschuck, in these proceedings.
[3] Planning of the Sector Test with Beam – E. Barbero Soto, in these proceedings.